Plant growth-promoting bacteria and desert re-vegetation

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Palm Springs, March 3 - 7, 2003

THE GOAL

EXTENDING THE POTENTIAL BENEFITS OF PLANT GROWTH - PROMOTING BACTERIA (PGPB)

(Such as *AZOSPIRILLUM* AND OTHER BENEFICIAL MICROBES)

FROM IMPROVING AGRICULTURAL PLANT YIELDS

TO ENVIRONMENTAL SOLUTIONS.

DESERT REFORESTATION AIDED BY PLANT GROWTH-PROMOTING MICROORGANISMS

THE GOAL : PREVENTING SOIL EROSION AND REDUCING DUST POLLUTION

BENEFICIAL MICROBES : **PGPBs** AND **MYCORRHIZAL FUNGI** **MAY AID** IN REVEGETATION OF THE DESERT

A SCENARIO FOR AN ECOLOGICAL DISASTER IN THE DESERT –

A TRUE STORY FROM NORTHWESTERN MEXICO

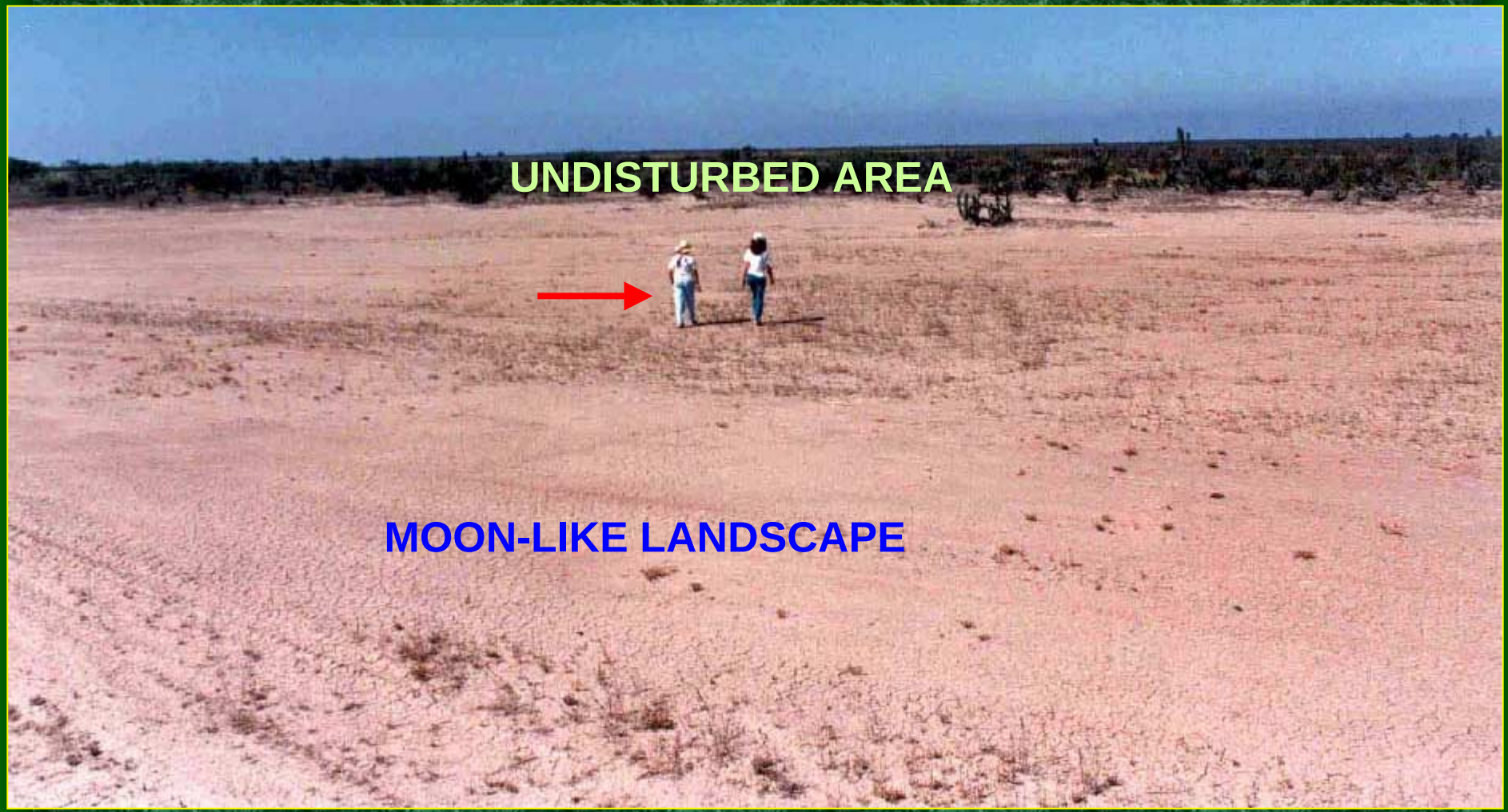
UNUDISTURBED DESERT OF THE FLATLANDS OF BAJA CALIFORNIA

CLEAR-CUTTING OF GIANT CARDON CACTI TO MAKE ROOM FOR AGRICULTURE IN BAJA CALIFORNIA

THREE YEARS AFTER CLEAR-CUTTING OF CARDON

LONG-TERM DESERTIFICATION

(ABOUT 20 YEARS AFTER CLEAR-CUTTING)

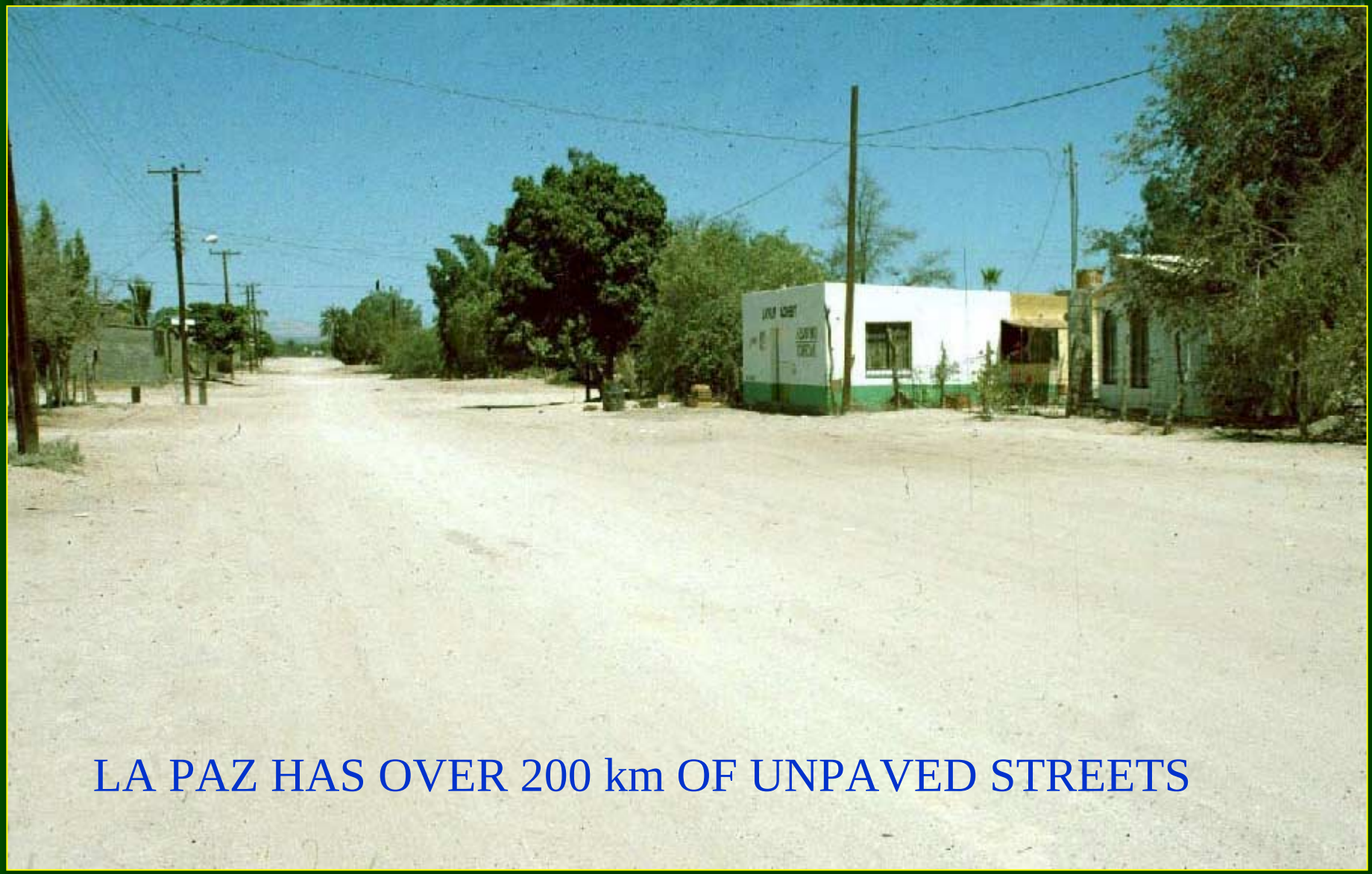


TYPICAL SOIL EROSION ON MODERATE SLOPES AFTER OVER-GRAZING

DUST DEVILS FORMED ON ABANDONED LANDS DURING A DRY SUMMER

CITY OF LA PAZ. EARLY SUNDAY MORNING. NO DUST!

UNPAVED STREET. COMMON IN RURAL NORTHWESTERN MEXICO



LA PAZ HAS OVER 200 km OF UNPAVED STREETS

DUST CLOUD ABOVE THE CITY OF LA PAZ ON A TYPICAL MORNING

CHRONIC RESPIRATORY ILLNESSES IN BAJA CALIFORNIA SUR, MEXICO

YEAR	POPULATION AFFECTED (%)
1992	32
1995	31
1997	33

MOST SUFFERERS ARE CHILDREN (source: Ministry of Health)

Our proposal for an environmental solution

Re-vegetate abandoned agricultural land with cacti and desert trees and control urban dust-creating areas.

For rural areas, many cacti are excellent top-soil stabilizers

The advantages of arborescent cacti for re-vegetation.....

- NUMEROUS!!!
- So, if they are such “dream plants,” why haven’t they been used?

THE MAIN PROBLEMS OF USING CACTI ARE …

- ALL ARE VERY SLOW GROWERS,
- MANY HAVE POOR ABILITY, AS SEEDLINGS, TO BECOME ESTABLISHED

THIS YOUNG CARDON IS OVER 100 YEARS OLD … ..

Proposed solution

Major issues in desert reforestation

- ✓How to establish a desert plant population
- ✓How to increase survival of plants after transferring them to the site
- ✓How to enhance their growth relative to the natural growth of vegetation

Possible microbial solutions?

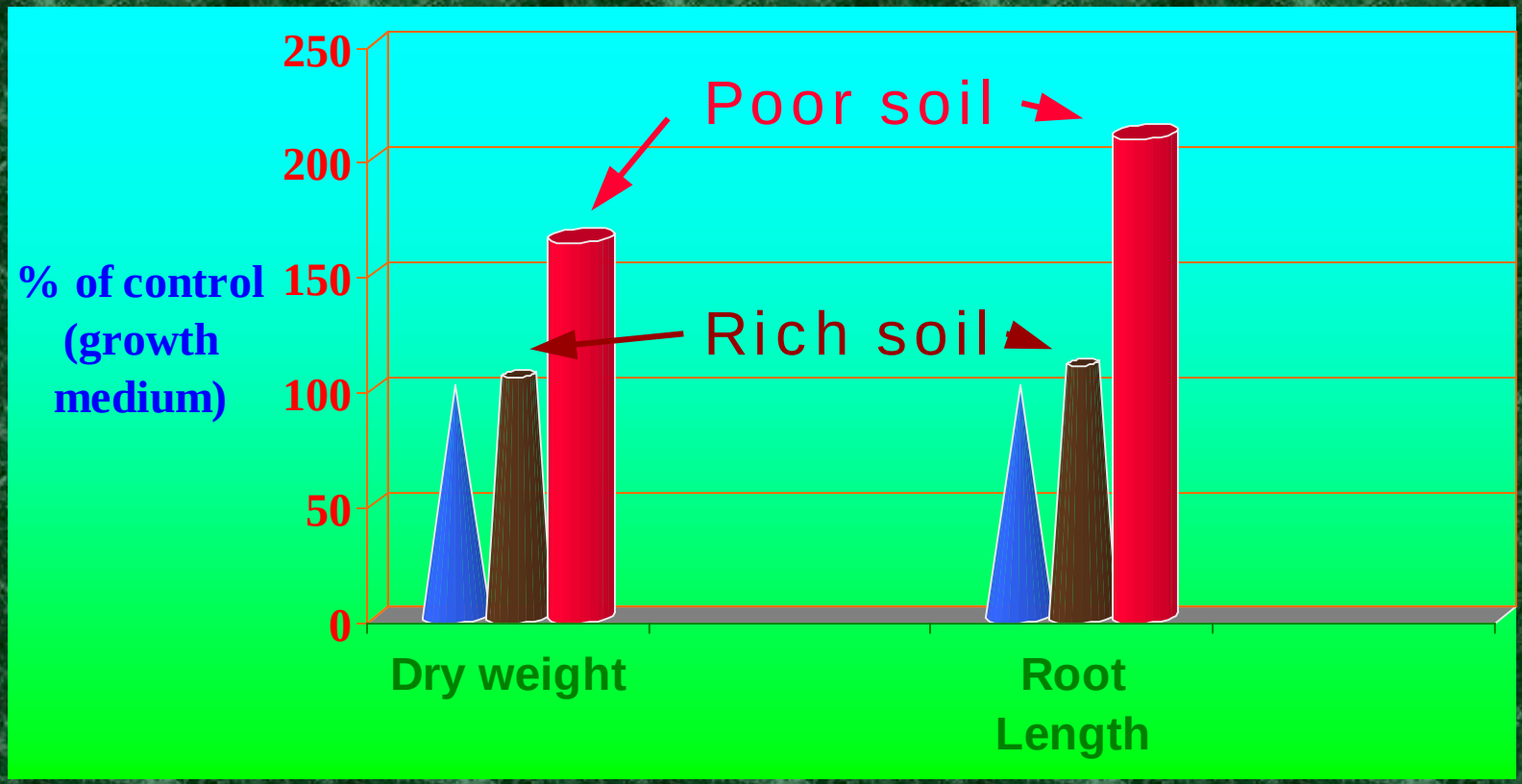
- ✓Artificial inoculation of desert plants with beneficial microorganism (bacteria and mycorrhizae fungi, alone and mixed)
- ✓Mimic typical vegetation reproduction patterns in the desert (nurse-tree-microbial micro-ecosystem)

INOCULATION OF CARDON CACTUS WITH *Azospirillum*

1 cm

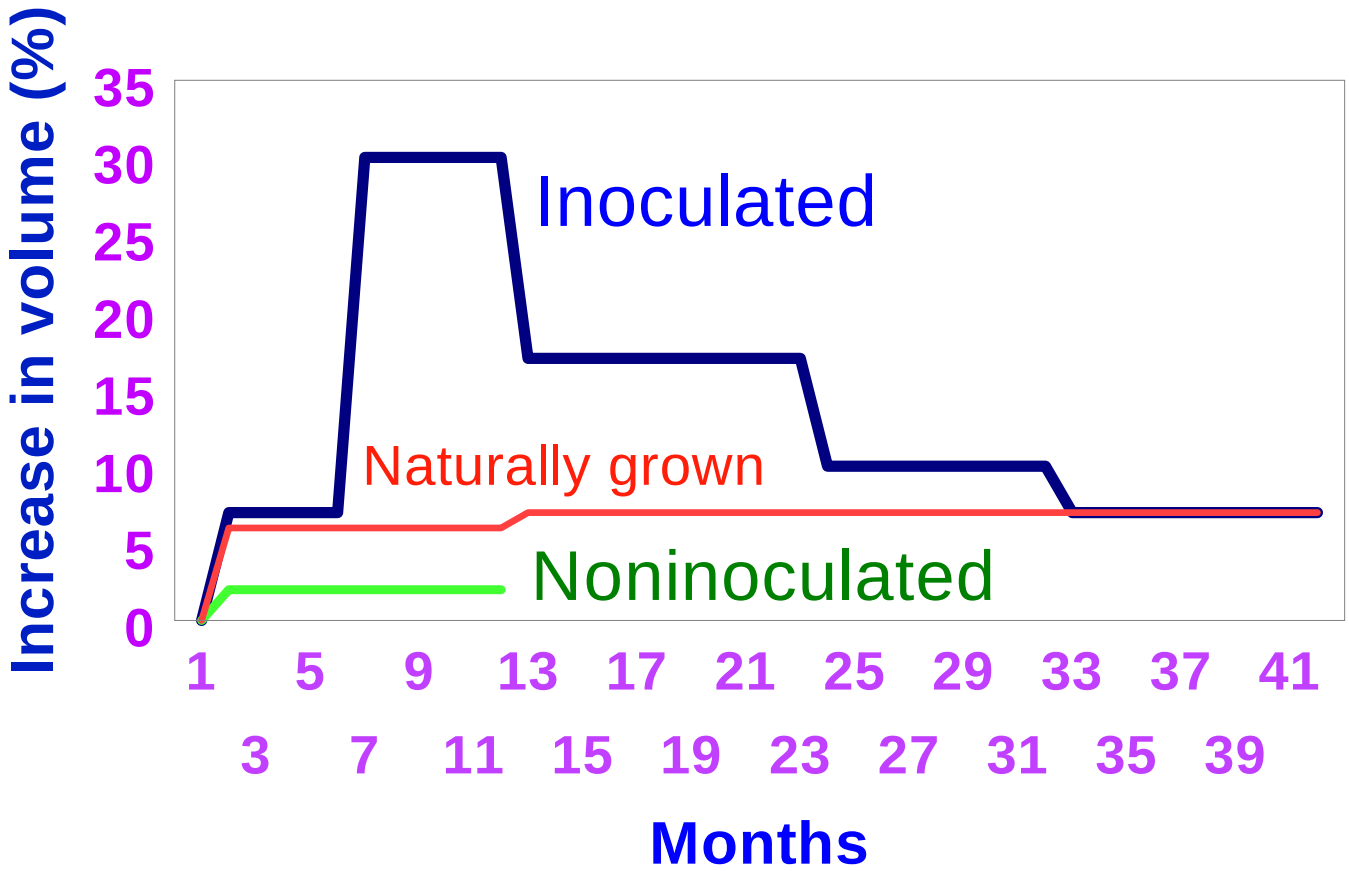
Puente and Bashan, 1993. Symbiosis

EFFECT OF INOCULATION WITH *AZOSPIRILLUM* ON CARDON CACTUS GROWING IN SOILS OBTAINED FROM NATURAL, VEGETATED SITES



Carrillo-Garcia et al. 2000. Restoration Ecology

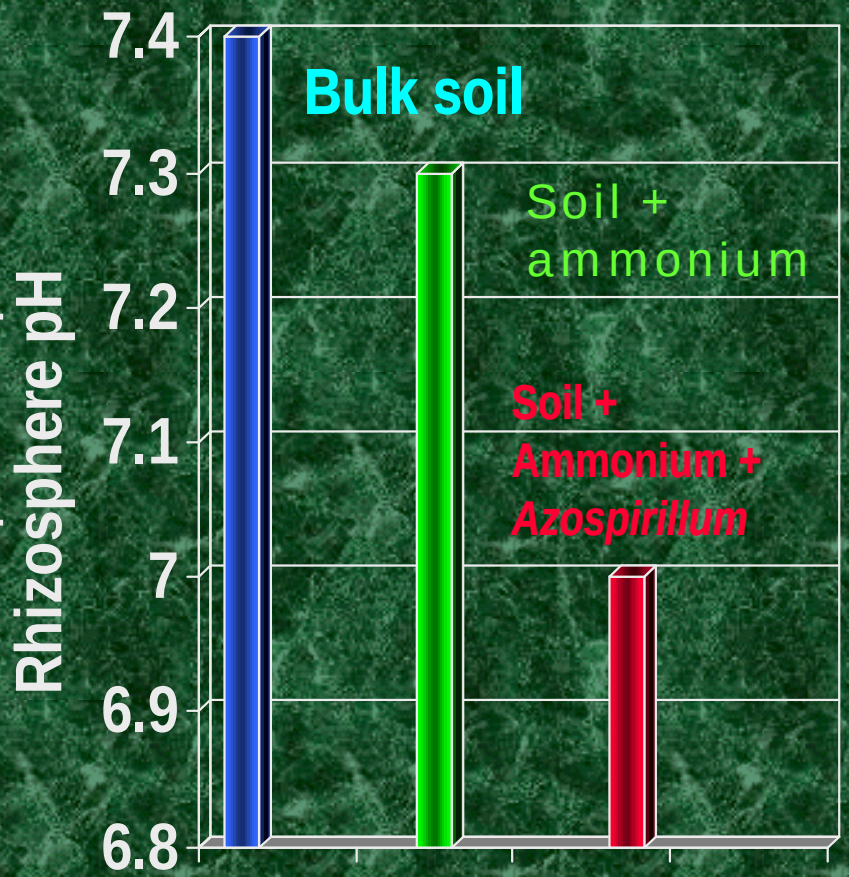
Increase in the volume of cardon cactus, grown in an eroded area, and inoculated with *Azospirillum brasilense*



Bashan et. al. 1999. Can. J. Microbiol.

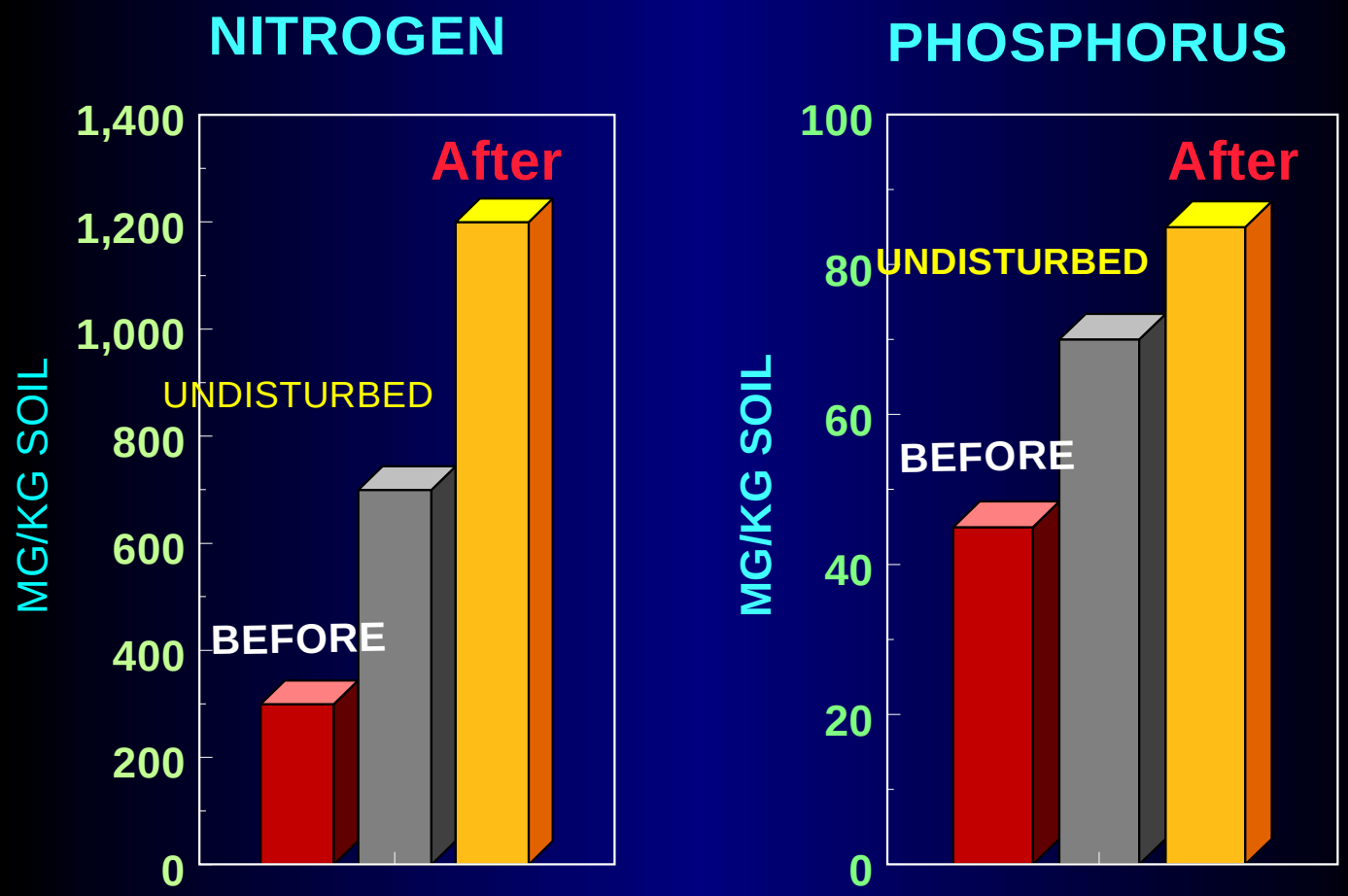
Increase in proton extrusion from roots and acidification of the rhizosphere of inoculated cacti

- Cacti inoculated with *Azospirillum* extrude more protons
- The pH of the rhizosphere is lower
- Adsorption of minerals increased



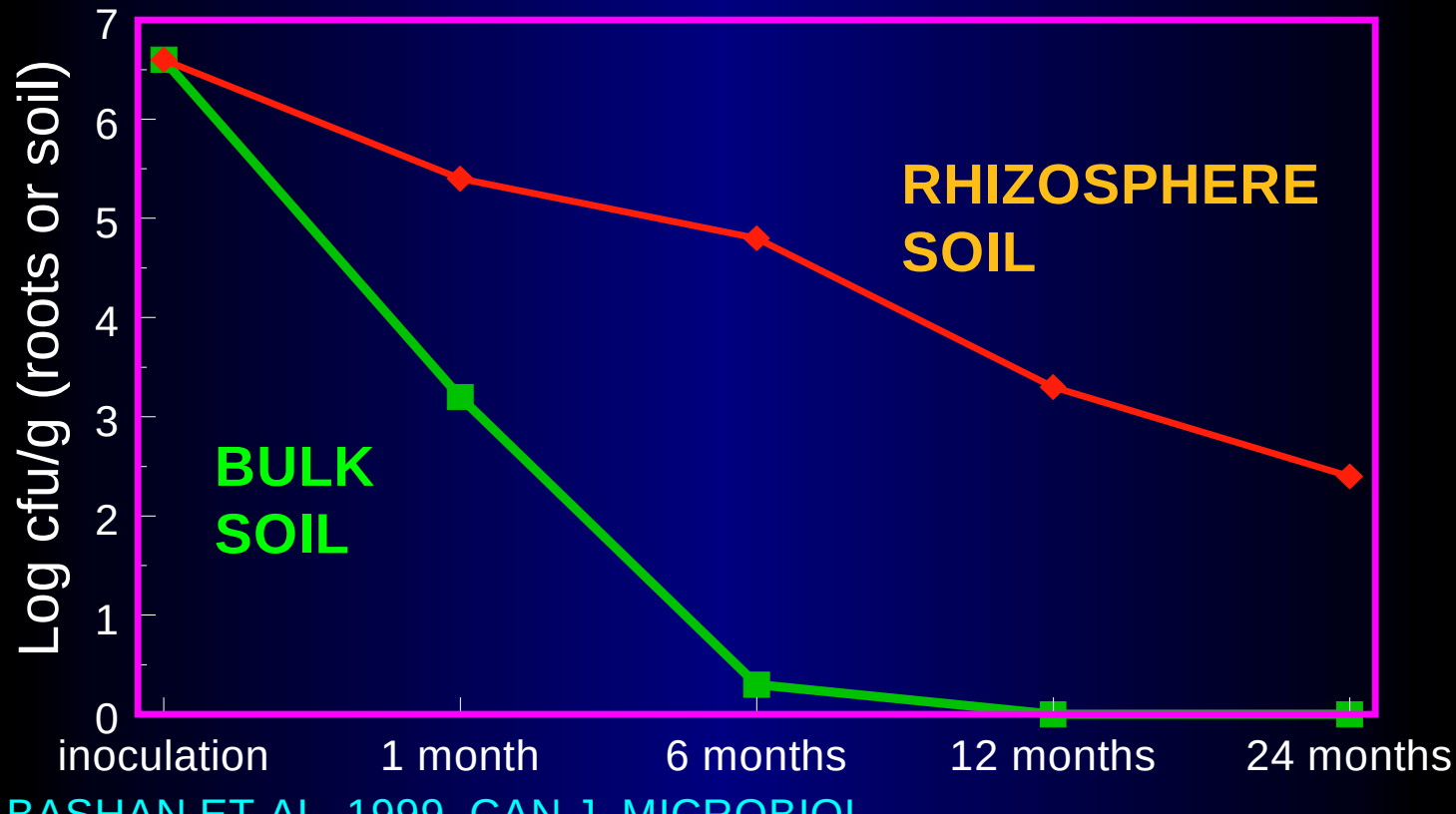
Carrillo et al. Naturwissenshften, 2002

THE LEVELS OF N AND P IN THE REVEGETATION AREA



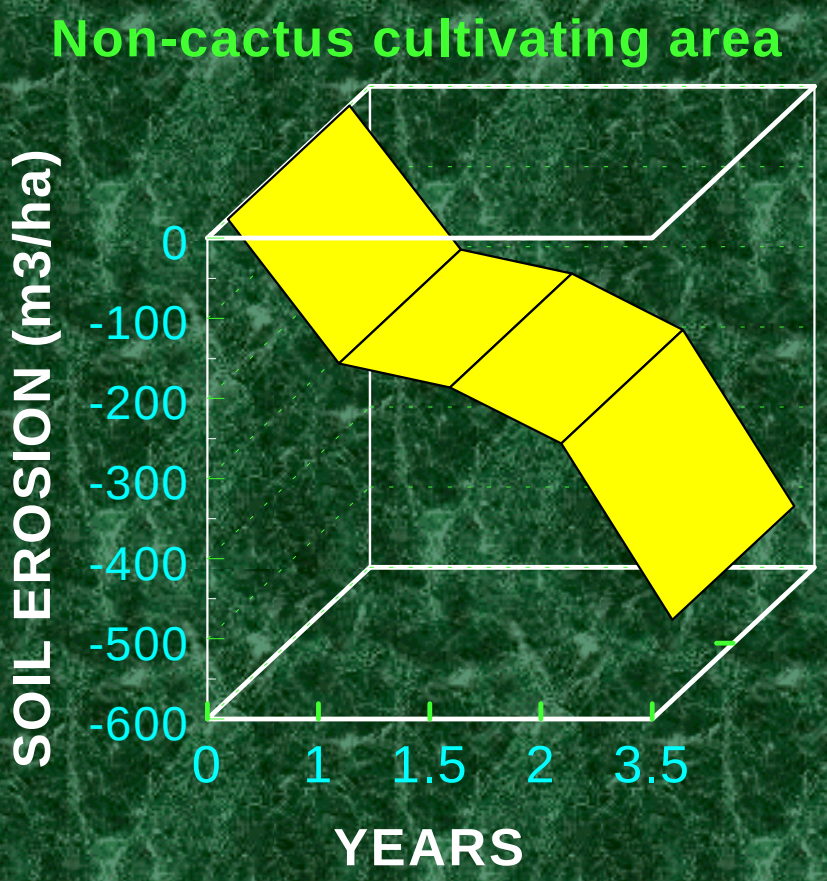
Bashan et al. Can. J. Microbiol. 1999

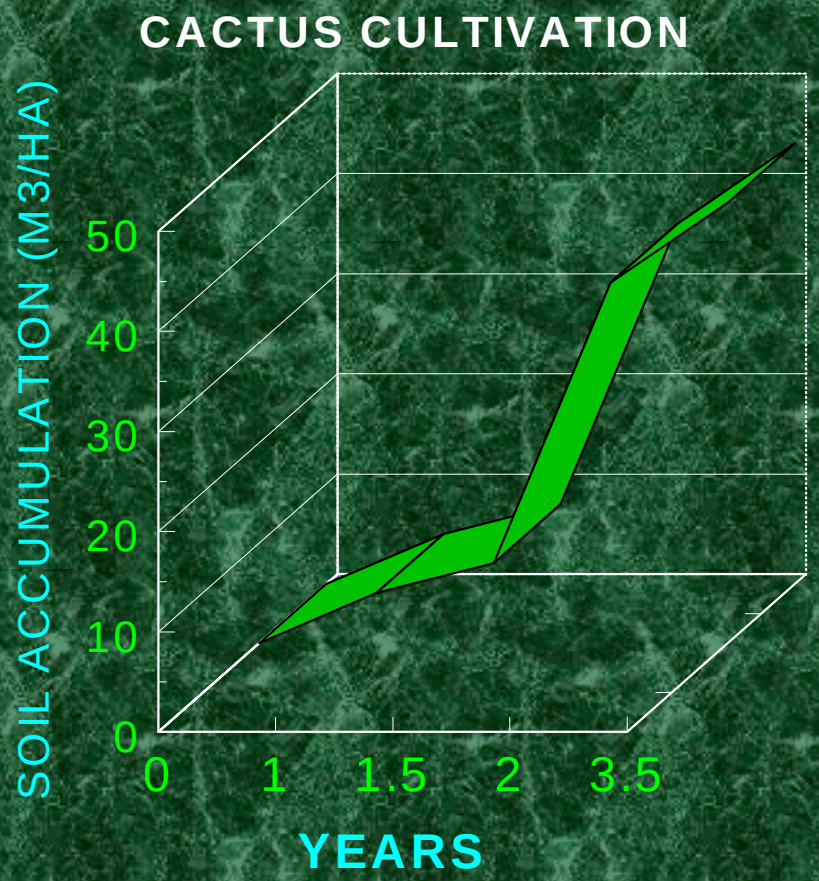
SURVIVAL OF *Azospirillum* IN THE RHIZOSPHERE AND BULK SOIL OF REVEGETATED AREA OF CARDON CACTUS



BASHAN ET AL. 1999. CAN J. MICROBIOL

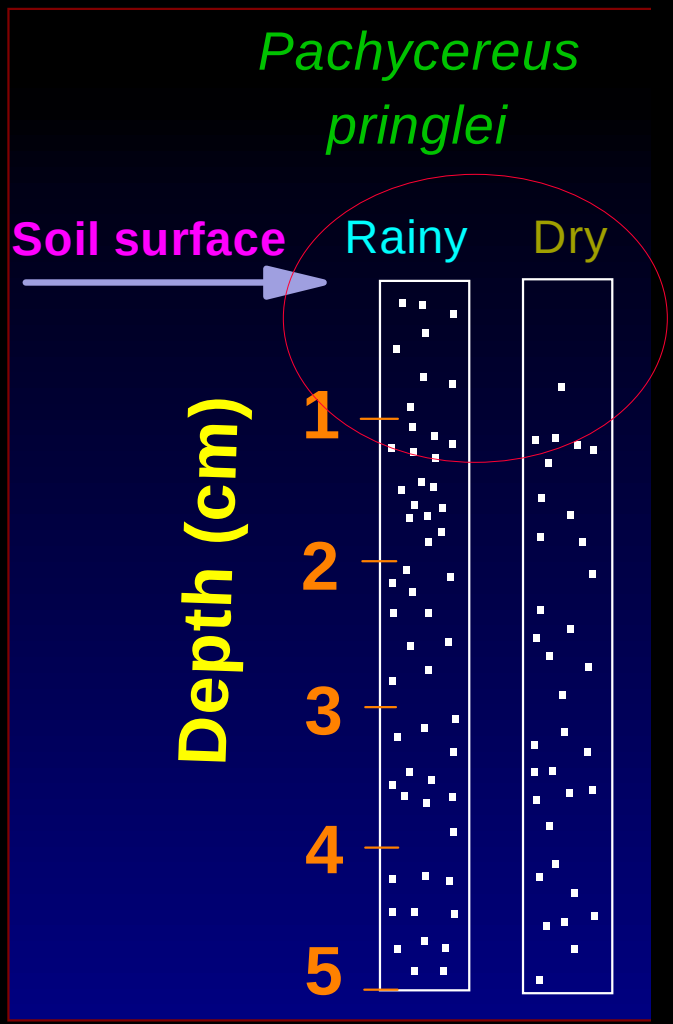
Soil erosion and soil reclamation with and without cactus cultivation

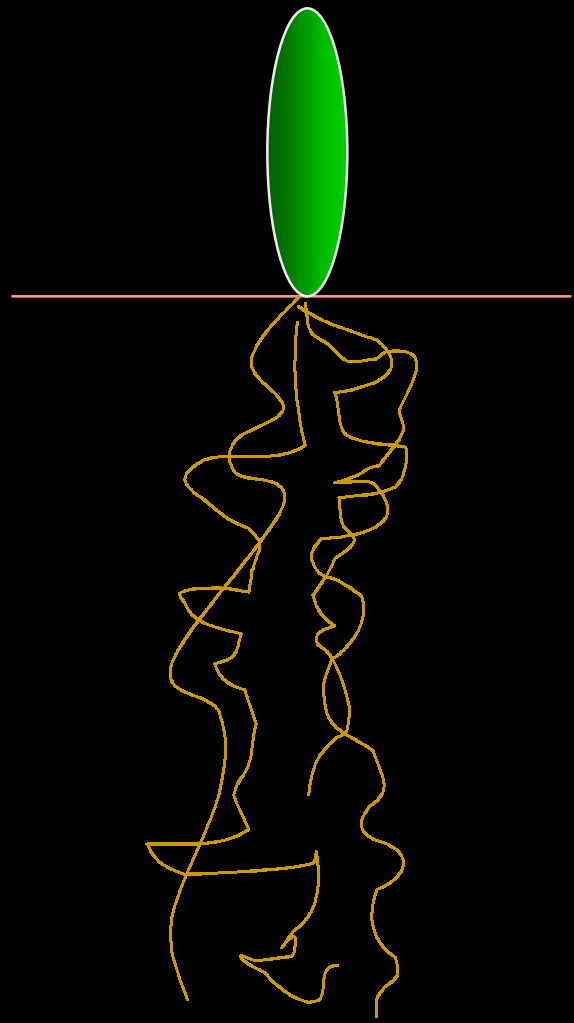




Bashan et. al. 1999

Distribution of small roots in the uppermost 5 cm topsoil in rainy and dry seasons 2.5 years after transplanting





Bashan et al. Can. J. Microbiol. 1999

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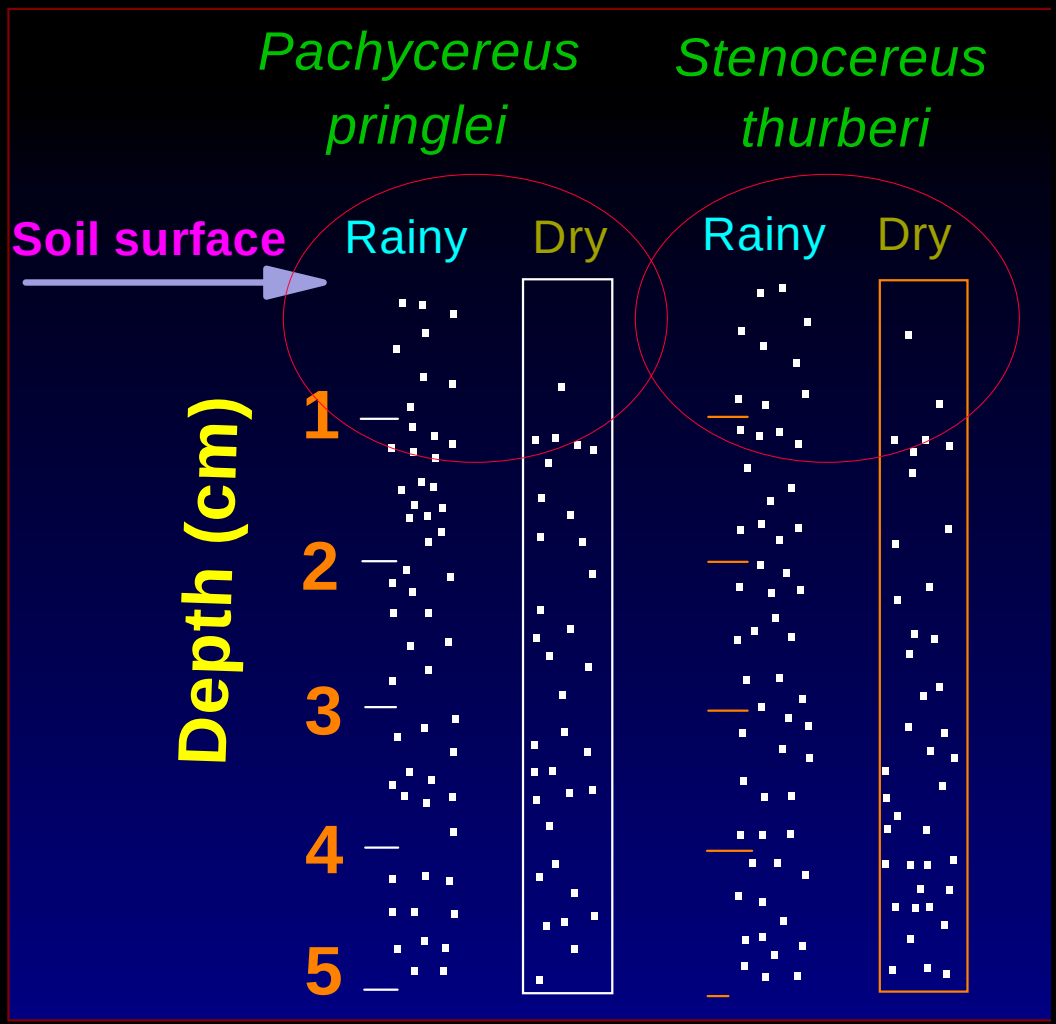

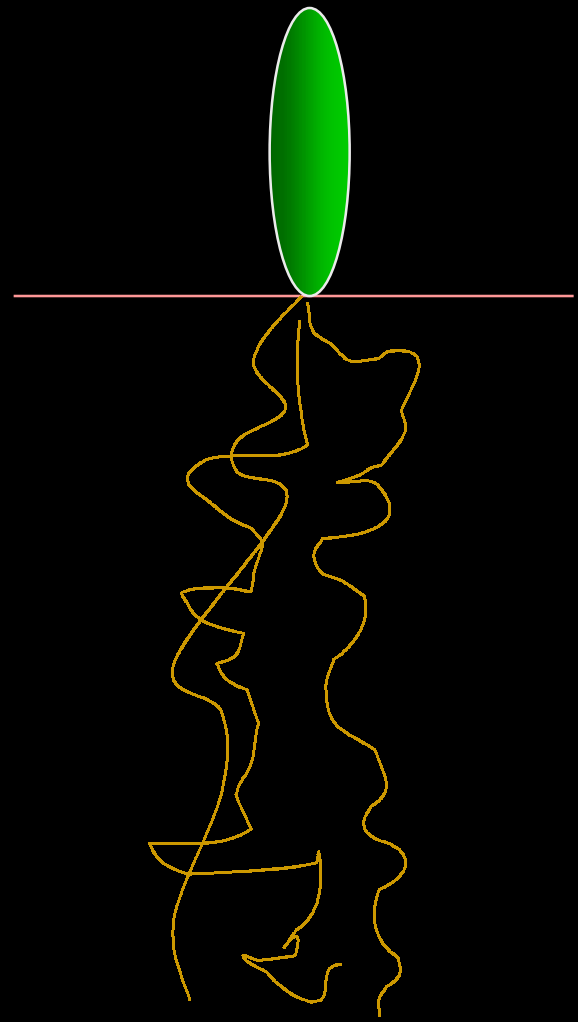

Bashan et al. Can. J. Microbiol. 1999

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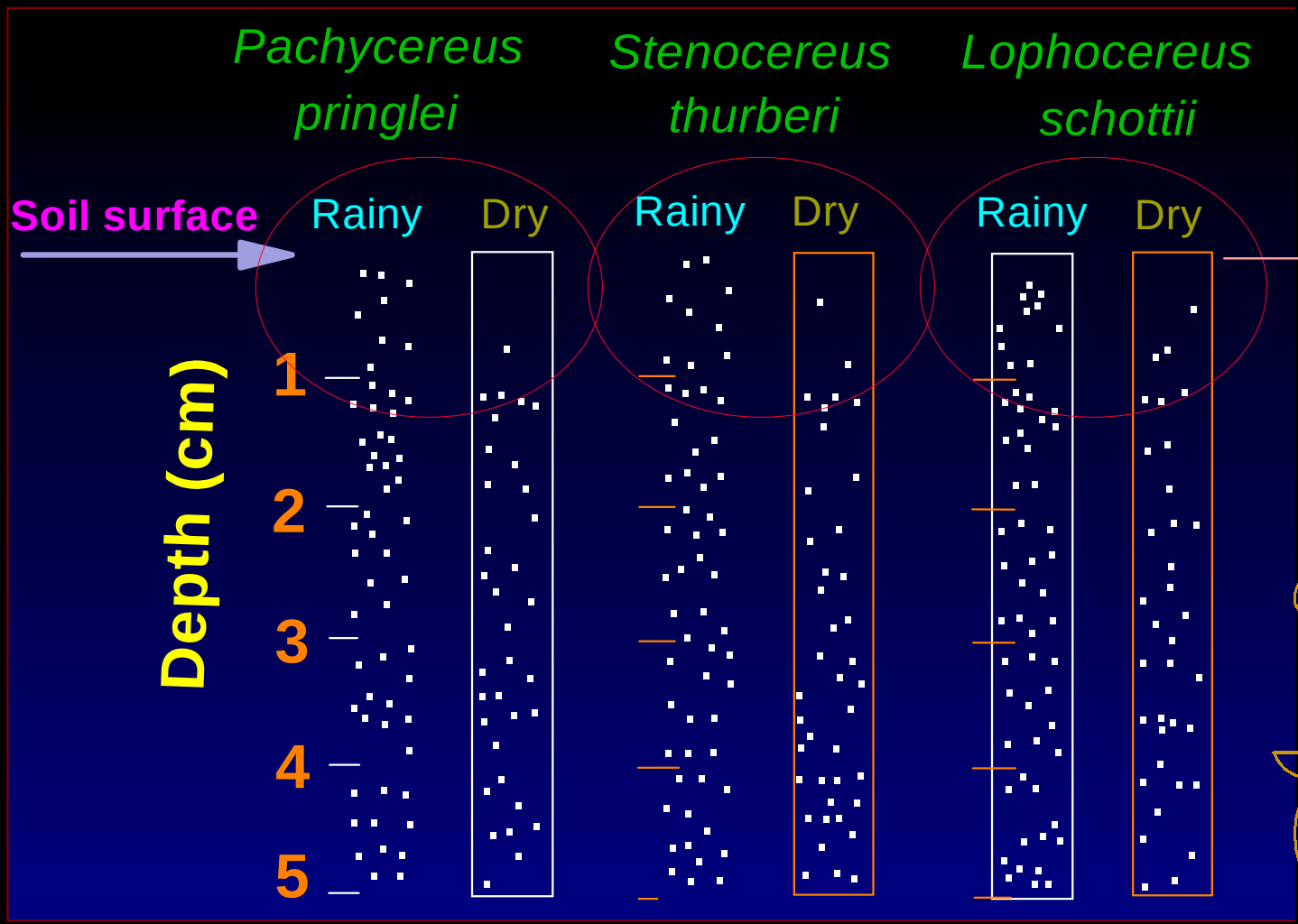


Bashan et al. Can. J. Microbiol. 1999

MECHANISM OF SOIL ACCUMULATION ASSOCIATED WITH CACTI

DUST LAYER

AND THE CYCLE GOES ON……..

Bashan et al., Can. J. Microbiol. 1999

CONCLUSIONS OF THIS STUDY

VS.

Natural

Inoculated

What happened to the inoculated cacti?

- Had a high survival rate
- Developed more rapidly

Compared to: uninoculated control cacti and natural vegetation during 3.5-years

What happened to the eroded urban soil?

- Soil erosion in the experimental area ceased.
- Small, but significant soil accumulation occurred.

THE USE OF ENDOPHYTES FROM WILD PLANTS AS PLANT GROWTH PROMOTERS

Accelerating creation of desert soil by microbes associated with plants?

CARDON CACTI GROWING IN ROCKS IN THE ABSENCE OF SOIL: AN EXAMPLE OF ROCK-WEATHERING PLANTS

Bashan et al. Plant Biology. 2002

MAMILARIA CACTI GROWING IN ROCKS IN THE ABSENCE OF SOIL: ANOTHER EXAMPLE OF ROCK-WEATHERING PLANTS

SMALL *MAMILARIA* CACTI AT DENSITIES OF UP TO 100 / SQUARE METER

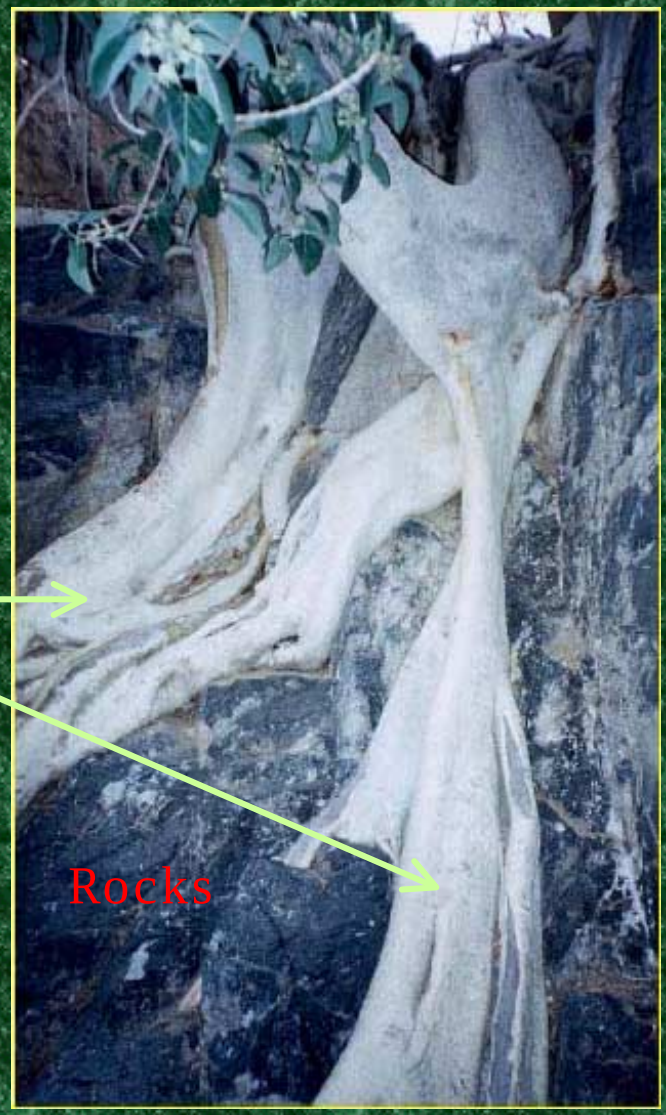
5 cm

Bashan et al. Plant Biology. 2002

WILD FIG TREES GROWING IN CLIFF: ANOTHER ROCK-WEATHERING PLANT

1 M

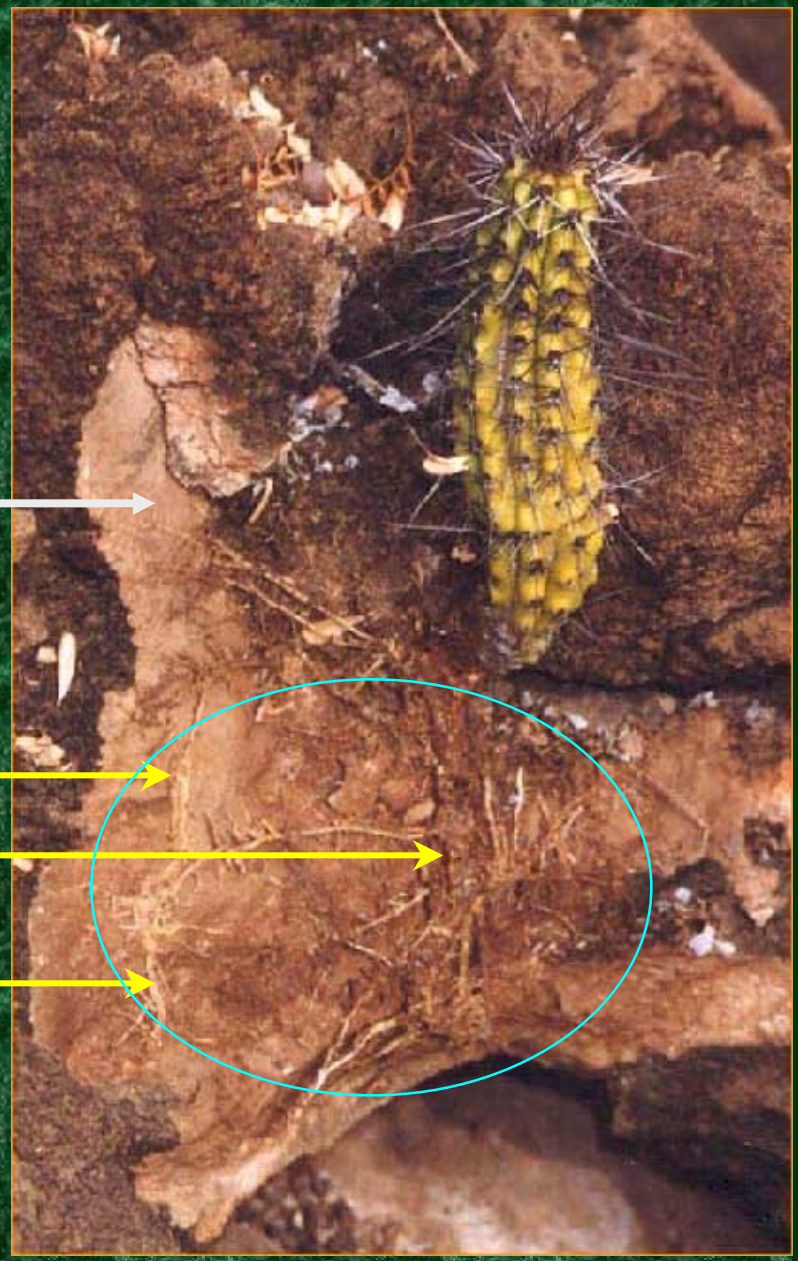
Roots



1 M

Bashan et al. Plant Biology. 2002

YOUNG CARDON CACTUS GROWING IN A ROCK WITHOUT SOIL

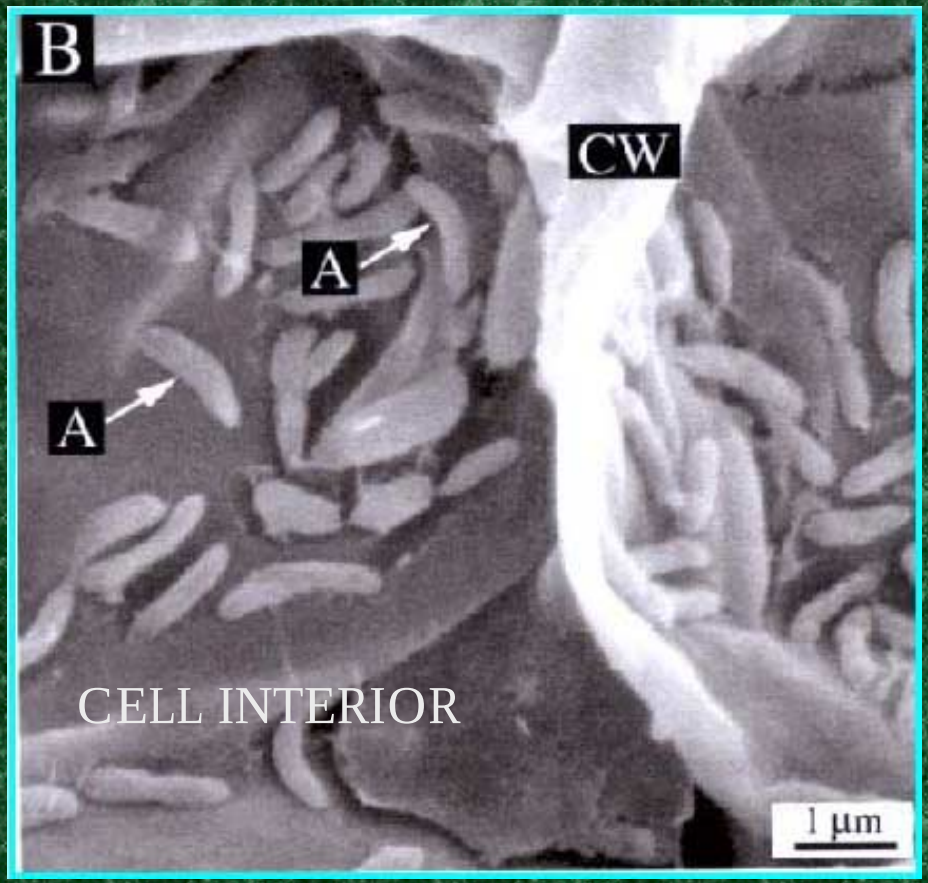


Bashan et al. Plant Biology. 2002

COLONIZATION OF ROOT SURFACE OF CARDON CACTUS GROWING IN ROCKS IN THE ABSENCE OF SOIL

PUENTE ET AL. 2003. Plant Biology (under consideration)

INTRACELLULAR COLONIZATION OF CARDON CACTUS ROOTS GROWING IN ROCKS WITHOUT SOIL



PUENTE ET AL. 2003. NATURE (UNDER CONSIDERATION)

What kinds of microbial communities are residing on the roots of cacti growing in rocks?

- ✓ Nitrogen fixers
- ✓ Phosphate solubilizers
- ✓ Plant hormones producers?
- ✓ Rock and mineral dissolving bacteria
- ✓ Mycorrhizae fungi?
- ✓ Fungi
- ✓ Actinomycetes
- ✓ Fluorescent pseudomonades

PUENTE ET AL. 2003. PLANT BIOLOGY

Inoculation of alder seedlings growing in crushed basalt with *Frankia*

(a nitrogen-fixing bacteria)

Inoculated

Uninoculated

(Li, unpublished)

USING PGPBs FOR DESERT REFORESTATION – GENERAL CONCLUSIONS

- INOCULATION OF CACTI WITH BACTERIA CAN ENHANCE THEIR ESTABLISHMENT AND GROWTH IN DISTURBED AREAS AND CAN STABILIZE SOIL
- ENDOPHYTIC MICROBES SHOULD BE INCORPORATED INTO TESTS FOR PROMOTION OF GROWTH OF DESERT PLANTS

MESSAGE TO TAKE HOME

THE USE OF PLANT GROWTH - PROMOTING MICROORGANISMS

SHOULD BE EXTENDED

FROM AGRICULTURAL TO ENVIRONMENTAL PROBLEMS

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